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COMPREHENSIVE REVIEW OF TO STUDY ABOUT POWER QUALITY IMPROVEMENT IN DISTRIBUTION NETWORK USING DSTATCOM

Mr. Parmar Dipakkumar G[1], Mr. Kumar Manoharjitsingh H[2]
[1]Lecturer In Electrical Engg., Government Polytechnic, Ahmedabad
[2]P.G. Student (Automation Control/Power System),
Electrical Engineering Dept., L.D. Engineering Collage
Ahmedabad, Gujarat, India

Abstract: A numerous of single-phase non-linear and linear loads may be supplied from three phase ac mains with neutral conductor. Then results excessive neutral current, increase reactive power and harmonics burden and unbalance. A three phase-four wire distribution static compensator (DSTATCOM) is applied for Compensation of neutral current along with reactive power compensation, harmonics elimination and load balancing. Issues of the power quality accurse numerous types of disturbance like voltage, current or frequency failure in distribution networks, sensitive industrial loads. In this approach, an mining of fundamental reactive and active power components of load currents is based on correlation and cross correlation functions in time domain. For evaluation of fundamental reactive and active power equipment of load currents. The performance of wire distribution static compensator is initiated satisfactory under time varying and load unbalanced. This paper shows the methods of correcting the supply voltage sag and swell in a distributed system, using equipment called D-STATCOM (Distribution Static Compensator. A D-STATCOM is basically working to inject a current into the system to correct the voltage sag and swell in the distribution system. D-STATCOM exhibits high speed control of reactive power to provide voltage stabilization, and also protects distribution system from voltage sag and /or flicker caused by rapidly varying reactive current demand.
Keyword: DSTATCOM, Power Quality, harmonic, synchronous reference frame

I. INTRODUCTION

Now a day, there has been a rapidly increased emphasis and concern for the power quality delivered to domestic, factories establishments and residences [17]. The mainly common issues in today power quality are voltage sag. Engineering of Power are increasingly disturbed over the electrical power quality. Basically electrical power is perhaps the most necessary raw material used by commercial and industry. Consider the three phase system voltage sag by nature is three phase phenomena, as an effect on phase-to-ground voltages and phase -to -phase voltages both. Quality of Power happens during fault condition, lightning strikes and other occurrences that unfavorably affect the line-voltage or/and current waveforms. Today, the FACTS devices are introduced to electrical system to improve the power quality of the electrical power system. The distribution systems are facing numerous problems in power quality due to the increase of different types of non-linear and linear loads such as solid-state controllers, which draw reactive, and harmonics and currents from ac mains [1–3]. Correspondingly, the single-phase non-linear and linear loads in the three-phase four wire distribution systems may lead to unbalance and excessive neutral current resulting in low power factor and losses increased [3]. Furthermore, poor power quality at AC source such like sag, swell, harmonics, notch, flicker, unbalance, etc. Since such harshness of power quality problems, numerous standards have been developed and are being enforced on consumers and utilities [4]. The corrective options reported for these problems include DSTATCOM (distribution static compensators), UPQC (unified power quality conditioner) and DVR (dynamic voltage restorer) are called under the generic name of custom power devices [2]. Quality of Power has become a very important problem recently due to the impact on electricity equipment, suppliers, manufacturers and customers. Generally in the power system power quality is described as the variation of current, voltage and frequency. Recent year, there are number of industries using high technology for process unit and manufacturing. This type of technology requires high reliability and high quality of power supply. The industries similar to computer, semiconductor and the equipments of manufacturing unit are very sensitive to the changes in the power quality supply [10]. This quality of power is necessary for proper operation of industrial processes which involves a better protection to the system for being swell and progressive for long swelled. Power quality issue like voltage swell, sag, harmonic distortion, unbalance, transient and flicker may have impact on customer devices which will cause malfunctions and loss of production. The last few years ago, seen a marked increase on the use of end-user equipment that is highly sensitive to poor quality controlled electricity supply. Numerous large industrial users are reported to have knowledgeable large financial losses as a result of even minor fall in the power quality of electricity supply. The solutions based on the use of the latest power electronic technologies prominently. Certainly, custom power technology, the low- voltage equivalent of the more widely known FACT (flexible ac transmission system) technology, this aimed at high-voltage power transmission applications, has emerged as a credible solution to solve many problems relating to continuity of supply at the end-user level. Both the FACTS and consumer power concepts may be directly credited to Electric Power Research Institute. D-STATCOM has been used to compensate reactive power and to prevent the voltage 'swell' and improve power quality problem.

II. ISSUE OF POWER QUALITY OF VOLTAGE SWELL

Quality of Power issues have many names and descriptions like Surges, spikes, transients, noise, voltage sag, voltage swell, interruption, are some common descriptions.

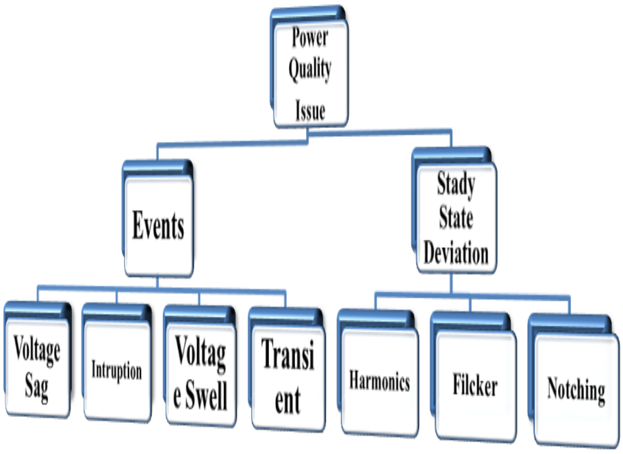

Figure 1: Issue of Power Quality

In this paper focus on voltage swell. Voltage swell is describe as a sudden drop in the R.M.S. (root mean square) voltage and is usually characterized by the remaining voltage. Voltage swell is considering short duration reduction in RMS voltage, caused mainly by short circuits, overloads and starting of large motors. Voltage swell is a one of the main power quality issue as compared to harmonics, flicker, EMI, noise etc. Basically loads can suffer harmful effect from voltage swell resulting in economic loss. The general characteristic of voltage swell will depend on location and type of fault in the system. Swells are the most common power disturbance effect is quite severe particularly in industrial and large commercial customers such as the damage of the sensitivity equipments and loss of daily productions and finances. Swell at the equipment terminal can be due to a short circuit fault hundreds of kilo meters away in the transmission system. Most of the current concentration in voltage swell is directed to voltage swell due to short circuit faults. These swells are the ones which causes majority of equipment tripping [5].

A. VOLTAGE SWELL:

IEEE standard 1159, definition of Voltage Swell is increase in the RMS voltage level to 110% - 180% of nominal, at that time the power frequency for durations of ½ cycles to one (1) minute. Generally is classified as a short duration voltage variation phenomena, which is one of the general categories of power quality problems [16].

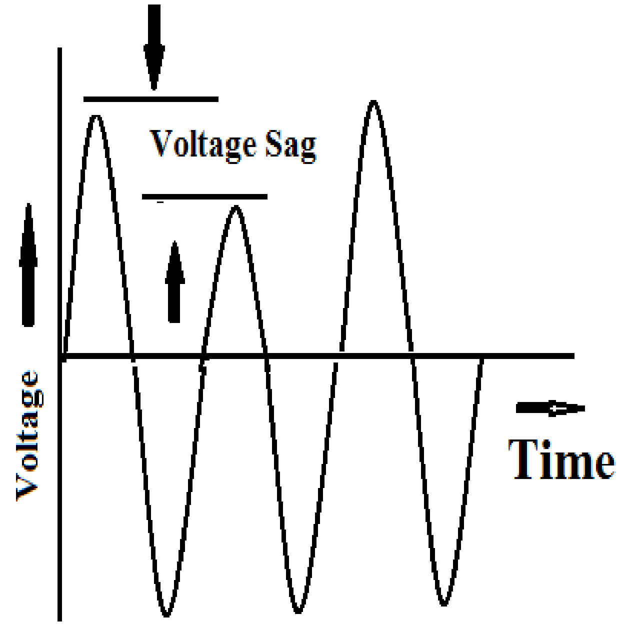

Figure 2: Voltage Swell

B. Voltage Swell Categories:

Characterized of voltage swells are duration and magnitude of RMS. The significance of the power quality problems during a fault condition is a function of the system impedance (i.e. the zero-sequence impedance relation to the positive-sequence impedance of the system), fault location and the grounding circuit configuration. For example, consider an ungrounded system; the line-to-ground voltages on the unfaulted phases can go as rise as 1.73 p.u. during a Single Line-Ground fault. On the other side, consider a grounded system close to the substation, there will be no voltage higher on the un-faulted phases because the substation transformer is usually connected delta-wye, this providing a low impedance zero-sequence path for the fault current [16].

C. Terminology Used for Voltage Swell:

The word "momentary over-voltage" is used like a synonym for the term swell. According to IEEE standard 1159-1995, swell magnitude is to be described by its residual voltage, in this condition, always greater than 1.0 p.u.

III. METHODOLOGY OF D-STATCOM

D-STATCOM is also known as shunt voltage controller consists of a two level voltage source converter. A dc energy storage device like a coupling transformer is connected in shunt to the distribution network and coupled with control circuit [13] as shown in the fig below. The voltage source converts the dc voltage across the storage device into a set of 3-Φphase ac output voltages. These type voltages are in coupled and phase with the ac system throughout the reactance of the coupling transformer. Appropriate adjustment of the magnitude and phase of the D-STATCOM voltage output allow effective control of reactive and active power exchanges between the DSTATCOM and ac system.

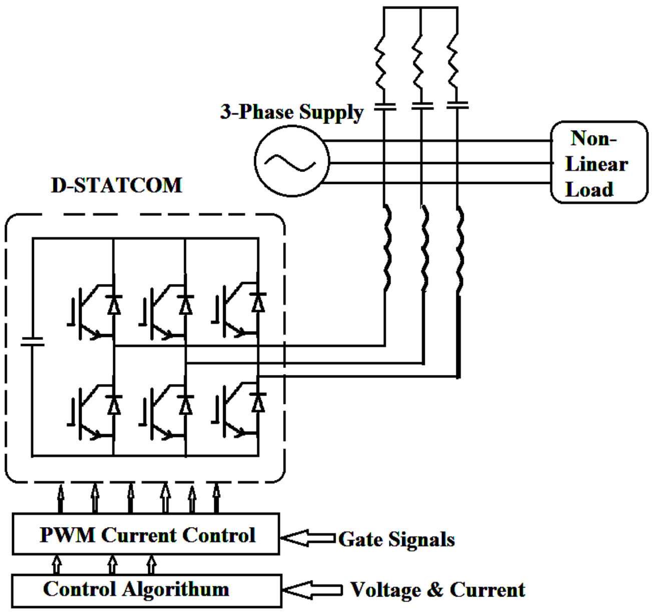

Figure 3: Basic Structure diagram of D-STATCOM

The voltage source converter is connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite different purposes.

a) Power Factor Correction

b) Regulation of Voltage and reactive power compensation and

c) Current Harmonics Mitigation.

Now a day D-STATCOM has widely used to voltage regulates system to improve voltage profile and reduce voltage harmonics, transient voltage disturbances and load compensation.

A. Basic Operation and Principal of D-STATCOM:

Generally active power filters are basically classified in to three types: Single phase, 3-Φ three wire and 3-Φ four wire systems to gather the requirements of the non-linear loads in the distribution systems. Basically 1-phase loads like TV's, domestic lights, air conditioners, and laser printers act as nonlinear loads and cause harmonics introduce in the power system. APF can also classify based on the type of converter, control scheme, topology and compensation characteristics. The mainly popular classification is based on topology like series and shunt.

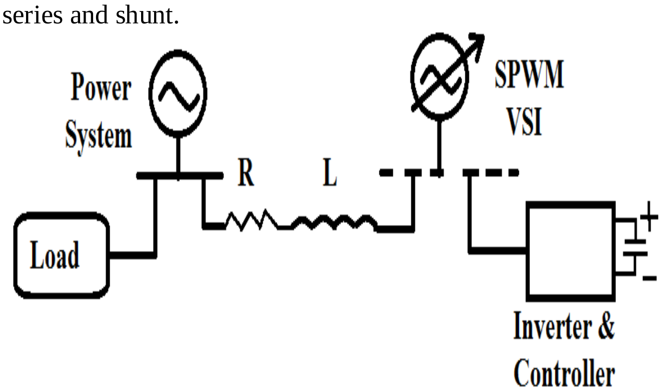

Fig 4: Basic block diagram of D-STATCOM [10]

D-STATCOM exists of a dc capacitor, 3-Φ inverter usually an IGBT or a GTO, ac filter and a control strategy. The basic electronic block diagram of the D-STATCOM is the VSI (voltage sourced inverter) that converts input dc voltage into a 3-Φ output voltage at fundamental frequency. It employs an inverter to convert the dc link voltage on the capacitor to a voltage source of adjustable Phase and magnitude. Thus the D-STATCOM can be treated like a voltage controlled source. Illustrate above figure the basic block diagram of the DSTATCOM, the resistance R and inductance L which represents the equivalent circuit elements of the step down transformer and the inverter are the main apparatus of D-STATCOM. The DSTATCOM reactive power output can be either capacitive or inductive depending on the operation mode of D-STATCOM. Referring to the above figure the inverter controller is used to operate in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted, so that the D-STATCOM absorb or generates the desired VAR at the connection point. The output phase voltage of the thyristor based inverter is controlled in the similar way as the distribution system voltage Vs. At this time, we can see from the figure circuit diagram of DSTATCOM, the shunt current injected corrects the voltage sag by adjusting the voltage drop across the system impedance.

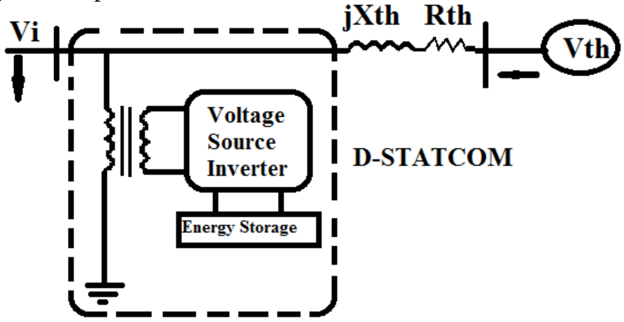

Figure 5: Basic circuit diagram of D-STATCOM [9]

The shunt current Ish value can be regulating by adjusting the converter output voltage. The shunt current injected Ish can be written as:

$$I_{SH} = I_L - I_i$$

The usefulness of the D-STATCOM in correcting voltage sag depends upon fault level value of the load bus. while the shunt current injected is kept in quadrature with VL, the preferred voltage correction is achieved without injecting any active power into the system. On the other side while the value of shunt current is minimized the same voltage correction can be achieved with minimum apparent power into the system.

IV. CONTROLLING OF D-STATCOM SYSTEM

Basically the controlling of D-STATCOM has two parts:

(a) Reference signal derivation using the required feedback signals.

(b) The gate signals generation using pulse width modulation current controller by comparing the reference and sensed signals. In this time, the proposed control technique for finding the reference current is based on the SRF (synchronous reference frame) theory and this technique is also called d-q-o technique. Now, the sensing load current is converted to reference rotating frame using 'sine and cosine' signals, with unity magnitude, generated by a PLL in-phase with the load voltage. Therefore the power of the disturbance of the electrical network is mitigated in the voltage waveform.

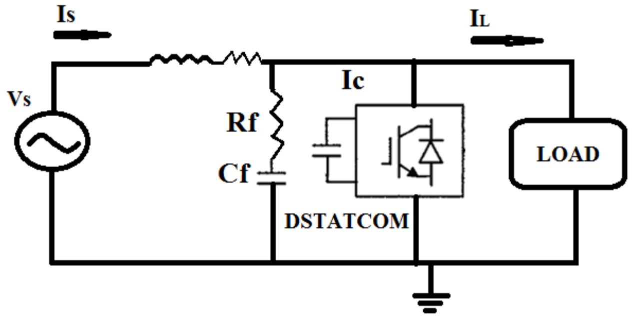

Figure 6: Single line diagram of DSTATCOM [1]

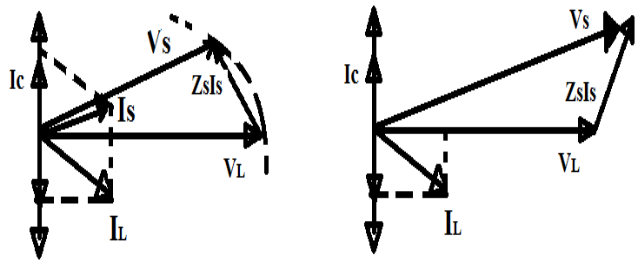

Figure 7: Phasor diagram for UPF operation (b) Phasor diagram for ZVR operation [1]

A. UPF operation

Consider a set of currents and voltages can be transformed into α–β–0 axis using the following transformation.

$$\begin{bmatrix} v0 \\ v\alpha \\ v\beta \end{bmatrix} = C = \sqrt{\frac{2}{3}} \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{pmatrix} \begin{bmatrix} v0 \\ v\alpha \\ v\beta \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i0 \\ i\alpha \\ i\beta \end{bmatrix} = C = \sqrt{\frac{2}{3}} \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{pmatrix} \begin{bmatrix} i0 \\ i\alpha \\ i\beta \end{bmatrix} \quad (2)$$

The reference d–q axis frame is finding by the angle θ with respect to the α–β transformation frame and the angle is obtained using a PLL. The transformation conversion from α–β–0 frame to d–q–0 frame equation is given bellow:

$$\begin{bmatrix} i0 \\ i\alpha \\ i\beta \end{bmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & \sin\theta \\ 0 & -\sin\theta & \cos\theta \end{pmatrix} \begin{bmatrix} i0 \\ i\alpha \\ i\beta \end{bmatrix} \quad (3)$$

All current components have an average value or dc component and an ac component or oscillating value like:

$$i_d = i_{ddc} + i_{dac} \quad (4)$$

$$i_q = i_{qdc} + i_{qac} \quad (5)$$

The strategy of compensating for reactive power compensation, operation of UPF considers that the source must bring the mean value of the d-axis component of the load current along with the active power component current for maintaining the dc bus and meeting the losses in DSTATCOM. The output of proportional– integral (PI) controller at the dc bus voltage of DSTATCOM is measured as the current for meeting its losses.

$$i_{loss} = i_{loss(n-1)} + K_{pd}(v_{de} - v_{de(n-1)}) + K_{id}v_{de(n)} \quad (6)$$

Here, Kid is the Proportional and the Integral gains of the dc bus voltage. The source reference current is,

$$i_d^* = i_{ddc} + i_{loss} \quad (7)$$

The source reference current must be in-phase with the voltage at the PCC (Point of Common Coupling) but with no zero-sequence component. Therefore the equation is obtained by the following reverse transformation;

$$\begin{bmatrix} is0 \\ is\alpha \\ is\beta \end{bmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix} \begin{bmatrix} 0 \\ id \\ 0 \end{bmatrix} \quad (8)$$

The source reference current in the a–b–c frame is obtained by reverse transformation of the above current vector:

$$\begin{bmatrix} isa \\ isb \\ isc \end{bmatrix} = C = \sqrt{\frac{2}{3}} \begin{pmatrix} 0 & 1 & 0 \\ 0 & -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ 0 & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{bmatrix} is0 \\ is\alpha \\ is\beta \end{bmatrix} \quad (9)$$

B. ZVR OPERATION:

The ZVR compensating operation strategy considers that the source must bring the same d-axis component, id as mentioned in Eq. (7) beside with the sum of q- axis current (iqdc) and the component obtained from the propagation integration controller (iqr) used for regulating voltage at PCC using the PI controller. The PI controller output is considered as the reactive component of current (iqr) for zero voltage regulation of ac voltage at point of common coupling. The ac terminal voltage amplitude at PCC is calculated from the ac voltages as,

$$v_{Lt} = (2/3)^{1/2}(v^2_{sa} + v^2_{sb} + v^2_{sc})^{1/2} \quad (11)$$

$$i_{qr(n)} = i_{qr(n-1)} + K_{pq}(v_{te(n)} - v_{te(n-1)}) + K_{iq}v_{te(n)} \quad (12)$$

The reference current supply q-axis will be represented as:

$$i_q^* = i_{qdc} + i_{qr} \quad (13)$$

The source reference current considers will be not in-phase with the voltage at the PCC but with no zero-sequence component. It is consequently obtained by the following reverse transformation equation as.

$$\begin{bmatrix} is0 \\ isa \\ is\beta \end{bmatrix} = C = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix} \begin{bmatrix} 0 \\ id \\ iq \end{bmatrix} \quad (14)$$

The source reference current in the a–b–c frame is obtained from equation is in (9).

$$i^*_{sn} = 0 \quad (15)$$

$$i_{sn} = -(i_{sa} + i_{sb} + i_{sc}) \quad (16)$$

C. REFERENCE NEUTRAL CURRENT SIGNAL:

The reference neutral supply current should be zero for compensating the neutral current of the load. Current-controlled using PWM for generating gating pulses: Using a current controller, it is worked sensed reference supply currents are compared and a proportional controller is used for filtering the current error in each phase before comparing with a triangular carrier signal to create the gating signals for six switches.

V. MODELLING OF DSTATCOM

A basic block diagram of the control scheme equipped with the voltage function regulation is illustrated in bellow figure. Here, two PI controllers are used for the control of dc bus voltage of DSTATCOM and ac voltage at PCC. The compensation current should lag or lead by 90^0 from the voltage. Generally D-STATCOM draws a lagging current to reduce the amplitude of the line-voltage, while the load injects capacitive reactive power. In also said that the DSTATCOM behaves as an inductor. The compensating current built a voltage drop and in that case, the line-voltage magnitude is kept at its reference value. Consider, while the load is an inductive, the DSTATCOM operates as a capacitor. Reactive current control through the control of DSTATCOM exists of the following function control as: harmonic mitigation, load balancing and neutral current compensation.

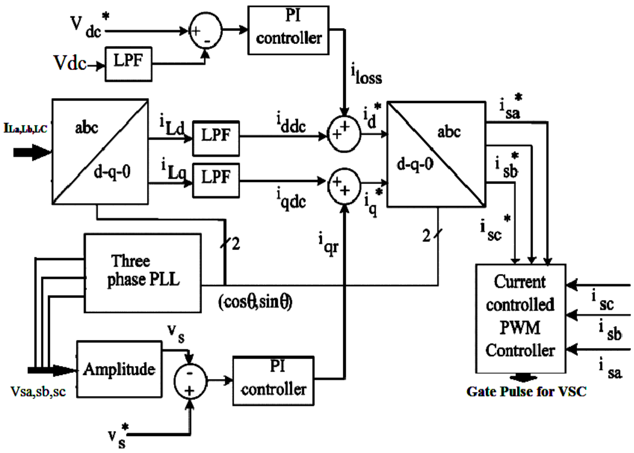

Figure 8: Basic Methodology operation of DSTATCOM [1]

VI. CONCLUSION

In this paper is present the investigation on role of D-STATCOM (Distribution Static Synchronous Compensator) introduces to compensate the voltage sag condition for improving the power quality with non-linear load. The 1-Φ non-linear loads may be supplied from three phase AC mains through neutral conductor. Here using of the non-linear loads as a result harmonics, excessive neutral current and reactive power is introduce. To compensate this problem, D-STATCOM (distribution static compensator) is used for neutral current compensation beside with reactive power compensation, harmonics mitigation and load balancing. The DSTATCOM performance has been verified for harmonic mitigation, reactive power compensation and load balancing for selection of loads in ZVR modes of operation.

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